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EFFECT OF RATION SIZE ON THE GROWTH AND FOOD CONVERSION OF *Macrobrachium rosenbergii*

Report No 87-91-K

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ABSTRACT

Growth-ration relationships were defined for 2, 5 and 15 g size classes of the freshwater prawn, *Macrobrachium rosenbergii*, fed commercial prawn pellets and fish flesh. Maintenance rations were 0.7, 0.5 and 0.25% of body weight/day for 2, 5 and 15 g prawns respectively. Optimum rations were 3.5, 2.5 and 0.9% of body weight/day and maximum rations were 5.5, 4.0 and 2.75% of body weight/day. It was determined that feeding at or near maximum ration levels would result in the most cost effective production of prawns in intensive culture systems where heating costs predominate. A ration and growth rate versus size curve was constructed for determining feeding level requirements for prawns.

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EXECUTIVE SUMMARY

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Biological Research Section
Chemical Research Department

Macrobrachium rosenbergii, a freshwater prawn, is being studied for development in an intensive thermal aquaculture scheme using low grade heat available at thermal power developments. In any aquaculture scheme efficient feeding regimes can maximize production and minimize time to harvest. The objective of this study was to define growth-ration relationships and food conversion efficiencies for a range of prawn sizes.

Three experiments using 2, 5 and 15 g prawns, fed commercial prawn pellets and fish flesh, were conducted. Each experiment examined six feeding levels ranging from zero percent dry weight of wet body weight to a level expected to exceed the animals' requirements. Optimum ration sizes were determined at 3.5, 2.5 and 0.9% of body weight per day and maximum ration sizes of 5.5, 4.0 and 2.75% of body weight per day for 2, 5 and 15 g prawns respectively. Maximum conversion efficiencies were estimated to be 32%, 37% and 59% for the 2, 5 and 15 g size classes respectively.

Results indicated that in prawn culturing systems where heating costs predominate and food costs contribute a relatively small portion of the total maintenance costs, prawns should be fed at maximum ration levels. This would lead to an early attainment of market size.

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To: Dr. D. Mills
Director of Research

EFFECT OF RATION SIZE ON THE GROWTH AND
FOOD CONVERSION OF *Macrobrachium rosenbergii*

1.0 INTRODUCTION

In aquaculture, efficient feeding regimes require timely adjustment of ration levels as the animals' requirements change. Inefficient feeding regimes may lead to significant monetary loss due to waste and/or poor growth.

The fundamental relationship of growth rate to rate of food uptake for fish was summarized by Brett (1979). Increasing ration size increases growth rate to a maximum. This relationship is described by an asymptotic curve with negative growth for zero per cent ration and growth increasing with ration size to a maximum positive growth rate. A number of factors related to feeding frequency and quantity limit the maximum daily food ration. Most important are satiation time, stomach capacity, feeding interval and the interaction of these factors (Brett, 1979). Sedgwick (1979) applied the principles outlined by Brett to penaeid shrimp. Shakuntala and Reddy (1976) and Ponnuchamy et al (1983) applied similar principles to the growth rate-food uptake relationship in a number of freshwater prawns.

A previous study (OHRDR 85-192-K) compared the growth of *Macrobrachium rosenbergii* raised on four different diets. A diet of commercial prawn pellets supplemented with fish flesh provided the best growth. The purpose of the present study was to define growth-ration relationships and food conversion efficiencies for 2, 5 and 15 gram size classes of the freshwater prawn *Macrobrachium rosenbergii* fed this diet.

2.0 METHODS

Six week old prawns were obtained from Amorient Aquafarms Inc., of Kahuku, Hawaii on July 28, 1986. Prawns were raised in a 7 x 6 x 0.8 metre concrete pool at 29 ^{o}C and fed a commercial prawn diet ad libitum prior to experimentation. Prawns used for the 2, 5 and 15 g experiments were 22, 32

and 51 weeks old, respectively. Prawns were size sorted for each experiment such that starting weights (± 10 per cent) for each treatment, ensured that the appropriate weight of 2, 5, and 15 g was attained at some time during the experiment.

Three experiments using 2, 5 and 15 g prawns were conducted. Each experiment examined six feeding rations ranging from zero percent dry weight of wet body weight to a level expected to exceed the animals' requirements at the experimental weight. Two gram prawns received feeding levels of 0, 1, 3, 5, 7 and 9 per cent of body weight. Five gram prawns were fed 0, 1, 2, 3, 5 and 7 per cent of body weight. Zero, 0.75, 1.5, 2.25, 3 and 4 per cent of body weight feeding rations were used for the fifteen gram animals.

Two and five gram animals were placed individually in glass chambers, 13.5 cm diameter and 7.5 cm high, fitted with 16/14 aluminium mesh screen tops. Polyethylene chambers, 27 x 20.5 x 15 cm, with 0.6 cm stainless steel grating tops were used for fifteen gram individuals. Twenty individuals were used per treatment for the two and five gram feeding levels. Ten individuals were used per treatment for the fifteen gram feeding level. Chambers containing individuals for each ration were submerged on the bottom of separate fiberglass tanks 1.22 metres in diameter and 0.76 metres high. A water volume of 700 litres was maintained in each tank by a central standpipe 0.6 metres in height. Each tank received heated, dechlorinated Etobicoke tap water at a rate of 1.5 litres per minute resulting in tank temperatures of approximately 29^{o}C with 3.1 volume exchanges per day.

Prawns were acclimated to the experimental environment and fed their appropriate experimental food ration for three days. The experimental period extended until significant growth occurred; 21 days for the 2 and 5 g experiments and 28 days for the 15 g experiment. Weights of individuals were recorded Mondays and Thursdays. Treatments (ration levels) were rotated among tanks on days animals were weighed so that by the end of the experiment each treatment had been applied to each tank. This minimized potential tank effects and allowed tank effects to be quantified if they existed.

The prawns were fed individually at 0800 hrs and 1300 hrs daily. The 0800 hr feeding consisted of Rangen Inc. shrimp food and the 1300 hr feeding consisted of previously frozen boston bluefish fillets. Each feeding contributed half the dry weight of the daily ration. Individual rations, as a percentage of new individual weights obtained Mondays and Thursdays, were readjusted Tuesdays and Fridays to maintain a constant per cent food ration for the duration of each experiment. Individual rations were weighed to two decimal places. Food was washed into each chamber via a glass tube using fresh water ensuring each animal had access to its total food ration. Cross contamination of food particles from chamber to chamber within a treatment did not occur.

3.0 RESULTS

The analysis of variance procedure (PROC ANOVA) of the Statistical Analysis System (SAS) was used to test the tank rotations to determine if any tank

effect existed. For each weight class tank effect was not significant ($p > 0.1$) ensuring the validity of the results (OHRDR 87-17-K).

3.1 Development of Growth Ration Curves

An attempt was made to describe the data using a non-linear model. The most reasonable fit was obtained in the form:

$$y = \alpha + \beta e^{x}$$

where y is the percent body weight gain per day and x is the food ration in percent of body weight per day. Alpha, beta and x are parameters of the model and e is the exponential (≅ 2.17). Results are summarized in OHRDR 87-17-K. Correlation coefficients were found to be 0.64, 0.67 and 0.46 for the 2, 5 and 15 g size class experiments respectively. The fitted models for the 2 and 5 g weight classes overestimated the data observed at ration size 1%. This underestimates the maintenance and optimum rations for these size classes.

The coefficients of the fitted models were subjected to F-tests to determine whether there were significant differences between means of per cent weight gain for each size class. Duncan's multiple range test was used to determine which ration classes were significantly different from each other. The results appear in Table I.

The non-linear models assisted in the statistical analysis of the results. However the models underestimated the maintenance and optimum rations for all size classes. Better estimates were obtained fitting smooth curves by eye. The results of the 2, 5 and 15 g weight class experiments are summarized as Growth-Ration curves in Figure I.

From zero ration (R_0), the growth ration curves rise from a negative value representing weight loss due to starvation (G_{starv}). The curves cross the point of zero growth rate (G_0) at the maintenance ration (R_{maint}). Optimum ration (R_{opt}) was estimated by drawing a tangent from the origin to a point where the ratio of growth to ration peaks. Mean percent weight gain/day continues to increase with ration size to a maximum growth rate (G_{ax}) for each size class. Growth and ration values for each size class are summarized in Table II.

3.2 Development of Conversion Efficiency Curves

Conversion efficiency (K) curves were derived directly from the estimated Growth-Ration curves by dividing wet weight gain by dry ration weight and multiplying by 100 to obtain per cent conversion efficiency. The resultant curves, fitted by eye, appear in Figure II. Estimated conversion efficiency for the 2 g size class peaked at approximately 32% at a food ration of 3.5% of the body weight per day. The observed maximum was 29% at the 3% food ration. For the 5 g animals a maximum 37% conversion efficiency was estimated at 2.5% ration. A maximum conversion efficiency of 49% was

TABLE I

SUMMARY OF DUNCAN'S MULTIPLE RANGE TEST ON MEANS
FOR 2, 5 AND 15 g SIZE CLASSES

SIZE CLASS	RATION (% BODY WEIGHT / DAY)					
2	0	1	3	7	9	5
	***	***	**********			
				**********		
5	0	1	2	3	5	7
	***	***	**********			
15	0	0.75	1.5	2.25	3	4
	***	**********				

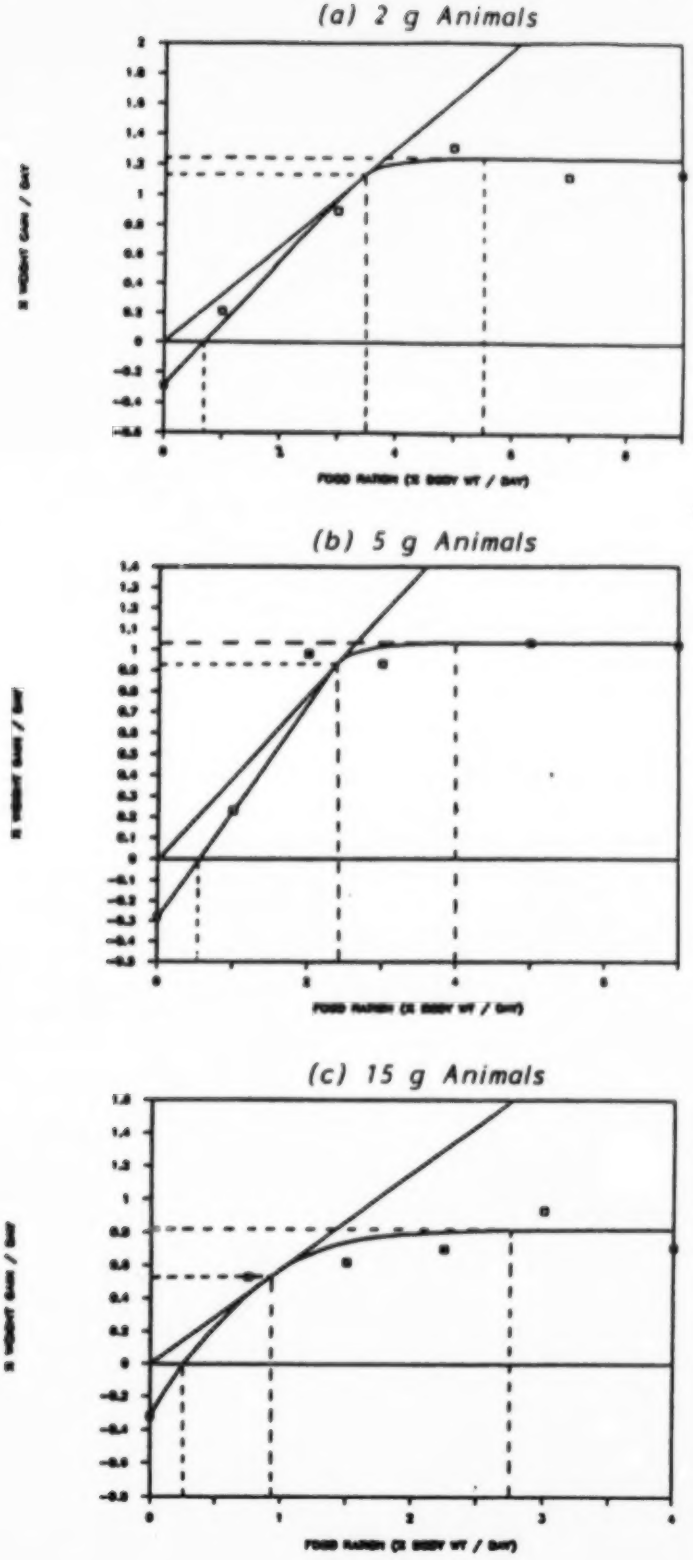

FIGURE I

WEIGHT GAIN CURVES OF (a) 2, (b) 5 AND (c) 15 g MACROBRACHIUM ROSENBERGII RELATIVE TO FOOD RATION LEVEL

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TABLE II

SUMMARY OF GROWTH AND RATION VALUES

FOR 2, 5 AND 15 g SIZE CLASSES

SIZE CLASS (g)	R_0 *	G_{starv} **	R_{maint} *	G_0 **	R_{opt} *	G_{opt} **	R_{max} *	G_{max} **
2	0	-0.3	0.6	0	4.0	1.1	5.5	1.23
5	0	-0.3	0.5	0	2.5	0.93	4.0	1.03
15	0	-0.3	0.25	0	0.9	0.53	2.75	0.81

* Food ration (% body weight / day)

** Weight gain (% weight gain / day)

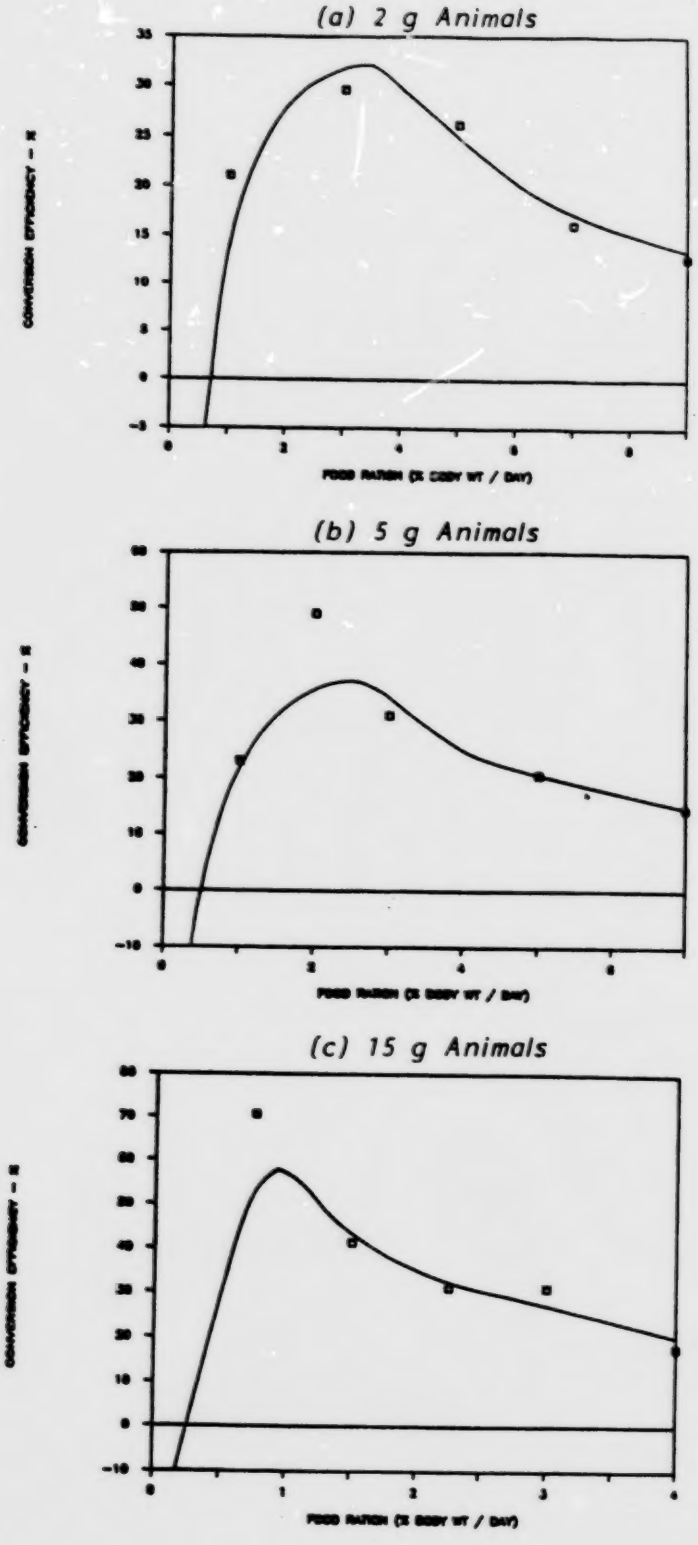

FIGURE II

FOOD CONVERSION EFFICIENCIES OF (a) 2, (b) 5 AND (c) 15g MACHROBRACHIUM ROSENBERGII RELATIVE TO FOOD RATION LEVEL

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observed at a 2% ration for the 5 g size class. Estimated conversion efficiency for the 15 g animals reached a maximum at 59% at 0.9% body weight per day ration with the observed maximum at approximately 70% at the 1% food ration level.

4.0 DISCUSSION

The results of the present experiment suggest that for *Macrobrachium rosenbergii* weight gain is dependent on food ration and the size of the animal as described by typical growth-ration and conversion efficiency curves commonly found for fish (Brett, 1979).

Results compare favourably with findings of other researchers examining the growth-food uptake relationship of both saltwater shrimp and freshwater prawns. Table III summarizes the results of these researchers.

Sedgwick (1979) described growth-ration curves for juvenile *Penaeus mergueinsis*. The shrimp were fed commercially prepared prawn pellets at four ration levels and two feeding frequencies. R_{maint}, R_{opt} and R_{max} were found to depend on feeding frequency.

Moulting frequency, growth and conversion efficiency of *Palaemon lamarrei* were examined by Shakuntala and Reddy (1976) in relation to daily ration levels of fresh *Gambusia affinis* flesh. Using their data and the curve fitting criteria used in the present study, R_{maint}, R_{opt} and R_{max} were recalculated on a dry weight basis. The resulting Growth-Ration curve appears in Figure III. Ponnuchamy et al (1983) examined the effects of different ration levels of the oligochaete *Tubifex tubifex* on survival, moulting and food conversion efficiency in two freshwater prawns, *Macrobrachium lanchesteri* and *Caridina weberi*. Their data were converted to units used in the present study and subjected to the same curve fitting criteria to simplify comparison of results. Growth-Ration curves for *Macrobrachium lanchesteri* and *Caridina weberi* appear in Figure III. Neither Shakuntala and Reddy nor Ponnuchamy et al adjusted ration size throughout the experimental period resulting in underestimates of R_{opt} and R_{max}. The generally higher values for R_{maint}, R_{opt} and R_{max} reported in these studies compliment the trend to higher values observed in smaller animals in the present study.

Results indicate that for 2 and 5 gram animals, increasing ration by a factor of 1.6 from R_{opt} to R_{max} results in an increase in weight gain of about 11% but increasing the food ration from R_{opt} to R_{max}, a factor of 3.1 for 15 gram prawns, increases weight gain by approximately 52%. Thus feeding at R_{opt} levels (maximum conversion efficiency) does not reduce weight gain significantly in smaller animals (2-5 g), however for larger animals (> 15 g), substantial increases in weight can be obtained by feeding at or near R_{max}, although conversion efficiency decreases approximately 50%.

Ling (1967) cultured *M. rosenbergii* in ponds starting with 60 day old postlarvae with an average weight of 2 grams. The mean weight of animals increased approximately 125% per month until the fifth month. Biomass increased dramatically during the last 3-4 months of a 6 month growout. In

TABLE III

RATION REQUIREMENTS AND CONVERSION EFFICIENCES
DETERMINED BY OTHER RESEARCHERS

RESEARCHER(S)	SPECIES	STARTING WEIGHT (g)	RATION (R_{maint} (% wet body weight/day))			MAXIMUM CONVERSION EFFICIENCY %
			R_{maint}	R_{opt}	R_{max}	
Sedgwick (1974)	*Penaeus mergueinsus* (saltwater)	0.13	2-3	5-9.5	12	55-125
Shakuntala and Reddy (1976)	*Palaemon lamerrei* (freshwater)	0.463	1	2.1	4	60
Ponnuchamy et al (1983)	*Caridina weberi* (freshwater)	0.123	2	5.4	6.7	25.5
Ponnuchamy et al (1983)	*M. lanchesteri* (freshwater)	0.408	1.4	2.35	3.25	15.7

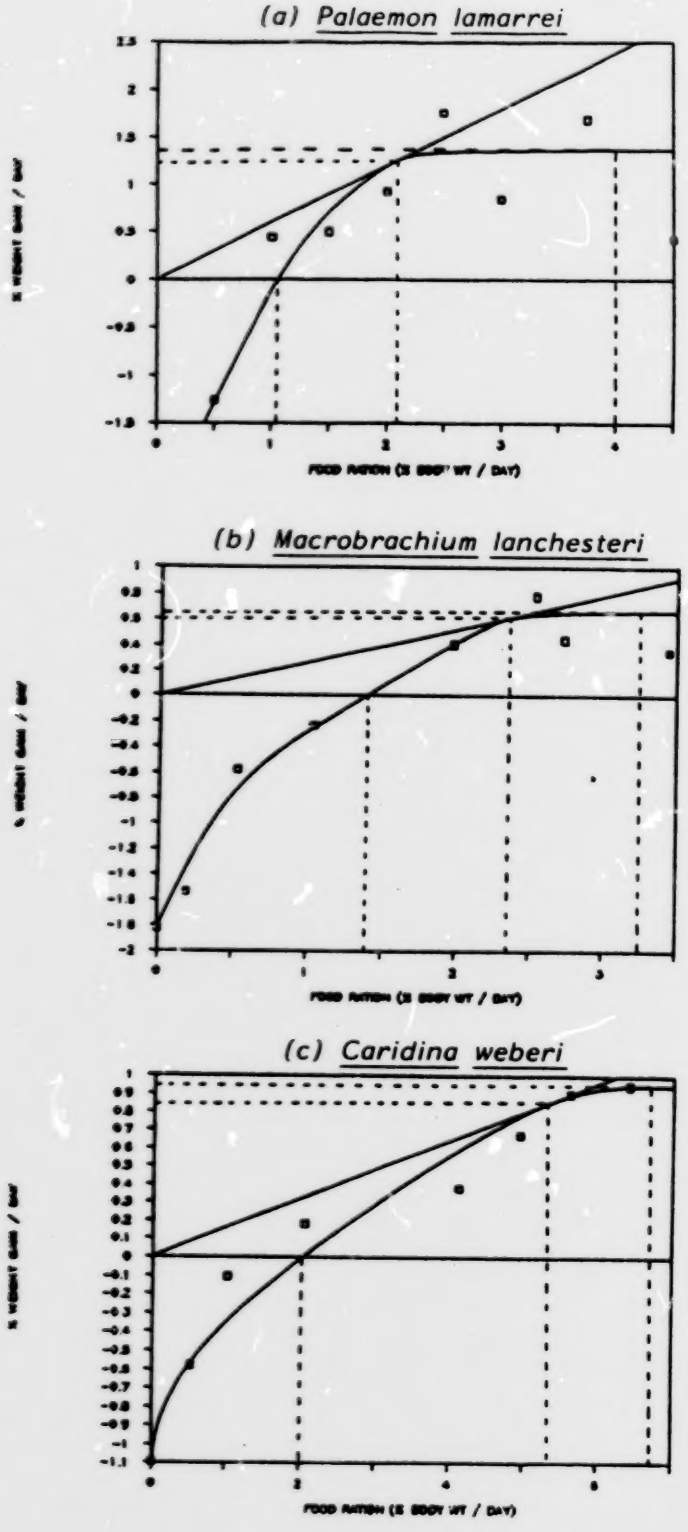

FIGURE III

WEIGHT GAIN RELATIVE TO FOOD RATION LEVEL OF (a) PALAEMON LAMARREI (b) MACROBRACHIUM LANCHESTERI AND (c) CARIDINA WEBERI DERIVED FROM STUDIES OF SHAKUNTALA AND REDDY (1976) AND PONNUCHAMY ET AL (1983)

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culture systems, where food costs are most critical, substantial savings can be made by feeding at R_{opt} levels early in the growout period (2-5 g) by taking advantage of optimum conversion efficiency with little effect on growth. Food costs could also be minimized later in growout by feeding rates between R_{opt} and R_{max} if time to harvest is not a critical consideration. In culture systems where food costs contribute a lesser portion of maintenance costs, i.e. where heating costs predominate, different feeding strategies can be used. Feeding 2-5 g prawns at R_{opt} rates would provide some food cost relief but must be balanced with extended growout times. Larger prawns would be fed at or near R_{max} during the last 3-4 months of the growout period ensuring maximum production with minimum time to harvest. By shortening time to harvest heating costs associated with intensive culture systems can be minimized.

Figure IV summarizes maximum growth and ration relative to size and can be used to estimate the ration required to produce maximum growth at any particular size. Maximum ration and growth as a percentage of wet body weight decrease in a log-log relationship with increasing size. Shakuntala and Reddy (1977) found the same relationship for the freshwater prawn, *Palaemon lamarrei*. Both food intake and growth per day as a percentage of body weight were inversely related to body size. They noted maximum conversion efficiency was not inversely related to body size.

The relationship between G_{ax} and size is described by the equation:

$$\log G_{max} = -0.2077(\log S) + 0.1544$$

with a correlation of -0.9994, where G_{max} is the growth rate in per cent wet body weight/day and S is the size in grams. Similarly, G_{opt} can be described by the equation:

$$\log G_{opt} = -0.3673(\log S) + 0.1778$$

with a correlation of -0.9689. Using these equations and iterative computer calculations, the predicted time to marketable size ($\geq$30 g, Mires, 1983) from a stocking size of 2 g would be approximately 295 days at R_{max} and about 400 days at R_{opt} for *Macrobrachium rosenbergii* fed a commercial prawn pellet and fish flesh diet.

5.0 SUMMARY AND CONCLUSIONS

1. Growth-ration relationships were defined for 2, 5 and 15 g size classes for the freshwater prawn, *Macrobrachium rosenbergii*. Maintenance rations were 0.7, 0.5 and 0.25% of body weight/day for 2, 5 and 15 g animals respectively. Optimum rations were 3.5, 2.5 and 0.9% of body weight/day and maximum rations were 5.5, 4.0 and 2.75% of body weight/day.

2. Maximum conversion efficiencies, determined at optimum ration size were estimated at 32%, 37% and 59% for the 2, 5 and 15 g size classes respectively.

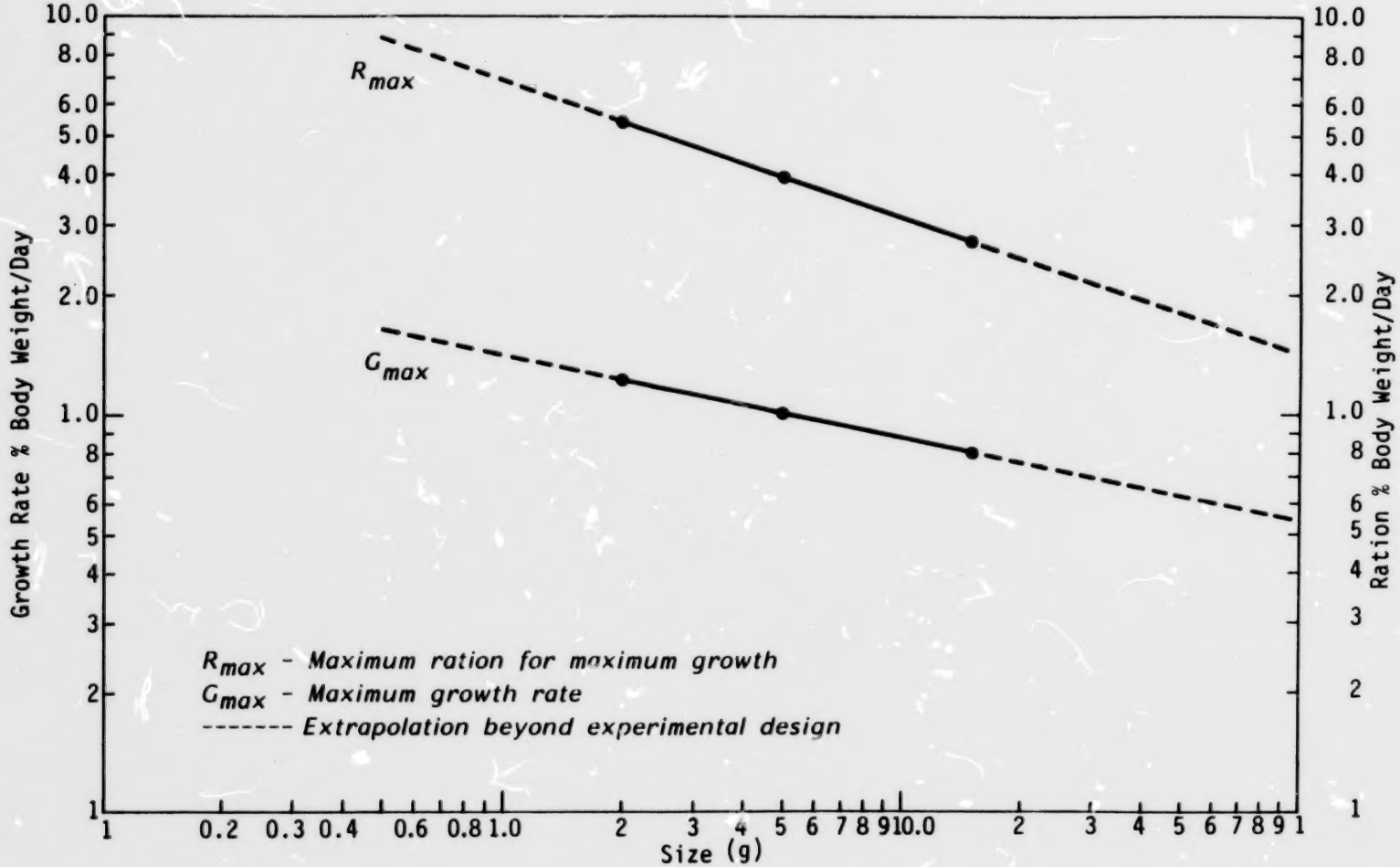

FIGURE IV

GROWTH RATE AND RATION VS SIZE

3. Ration size can be manipulated to some extent to minimize cost and maximize growth depending on the nature of the intensive culturing system.

4. In culturing systems where heating costs predominate, i.e. food costs contribute a smaller portion of total maintenance costs, prawns should be fed maximum rations for early attainment of market size.

5. Maximum ration and growth rate as a percentage of body weight vary in a log-log relationship with increasing prawn size. The maximum ration and growth rate versus size graph can be used for determining maximum feeding levels for prawn culture.

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